Numerical Simulations on Added Resistance and Ship Motions of KVLCC2 in Waves

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Contents

Motivations (1/2)

- Trend change of ship design and researches on ship performances

Before economic crises in 2008

After economic crises in 2008

Design draft and speed in calm water (14.5m, 23 knots for C/C)

Operational draft and speed in calm water (12.5~14.5m, 17~21 knots for C/C)

Operational draft and speed in calm water and seaway taking into account realistic weather conditions

Motivations (2/2)

- Benefits from studies on the ship added resistance
  - Realistic S.M., accurate estimation of the speed loss, opt. for weather routine
  - Faster and safer ship in actual sea conditions, and reduced operation costs
  - Prediction of the ship motions for ship safety in a seaway and coastal areas

- Regulations for global environmental protection from CO_2 Emissions
  - EEDI (Energy Efficiency Design Index): Design specific

$$EEDI\ \left[\frac{g}{ton \cdot NM}\right] = \frac{CO_2\ Emissions}{DWT \times Speed \times f_W}$$

  - f_W (coefficient of ship speed reduction, IMO and 27th ITTC seakeeping committee) non-dimensional coefficient indicating the ship speed reduction in representative sea conditions (i.e. Beaufort scale 6 considering mean sea condition of north Atlantic and north Pacific) of wave height, wave frequency and wind speed
  - EEOI (Energy Efficiency Operational Index): Operational & Voyage specific

$$EEOI\ \left[\frac{g}{ton \cdot NM}\right] = \frac{CO_2\ Emissions}{Cargo\ capacity \times Dist.\ of\ voyage}$$

Safety in a Harbour

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Main Particulars for KVLCC2

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Particulars	Unit	Full scale	Model scale (CFD)
Scale		1	80
LBP	m	320.0	4.0000
LWL	m	325.5	4.0688
B	m	58.0	0.7250
D	M	30.0	0.3750
T	m	20.8	0.2600
Displacement	m^3	312,622	0.6106
W.S.A.	m^2	27,194	4.2491
CB		0.8098	0.8098
LCB, fwd+	%	+3.48	+3.48
LCG, fwd+	m	11.1	0.1388
KG (VCG)	m	18.56	0.2320
GM	m	5.71	0.0714
Moment of inertia	Kxx/B, Kyy,zz /LBP	0.40, 0.25, 0.25	0.40, 0.25, 0.25

Numerical Methods and Modelling

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- Prediction of the added resistance due to waves

❖ 3-D linear potential method

- 3-D source-sink frequency domain with the zero-speed Greens functions
- Near-field approach (direct pressure integration for the calculation of the added resistance)
- Added resistance for regular waves in frequency domain

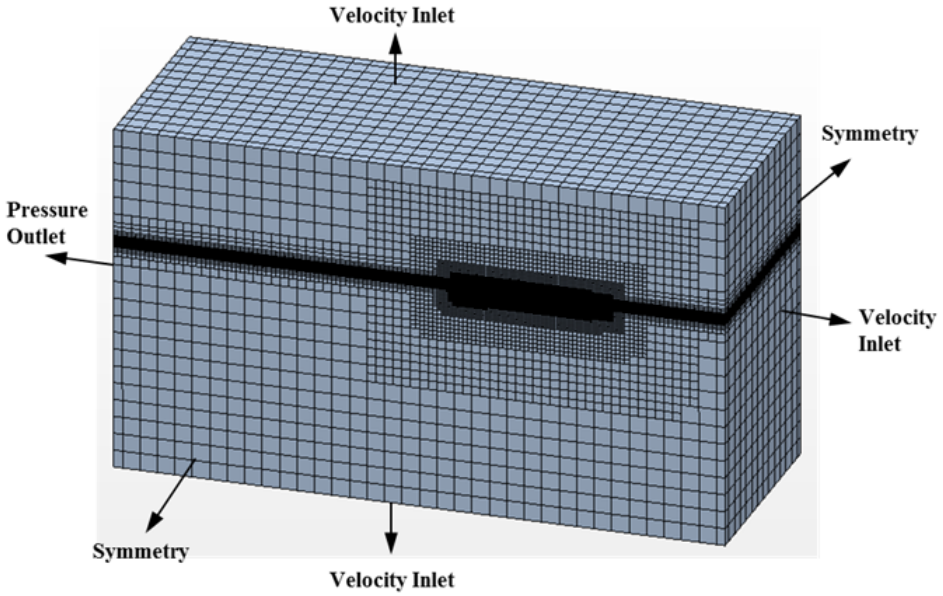
❖ CFD method

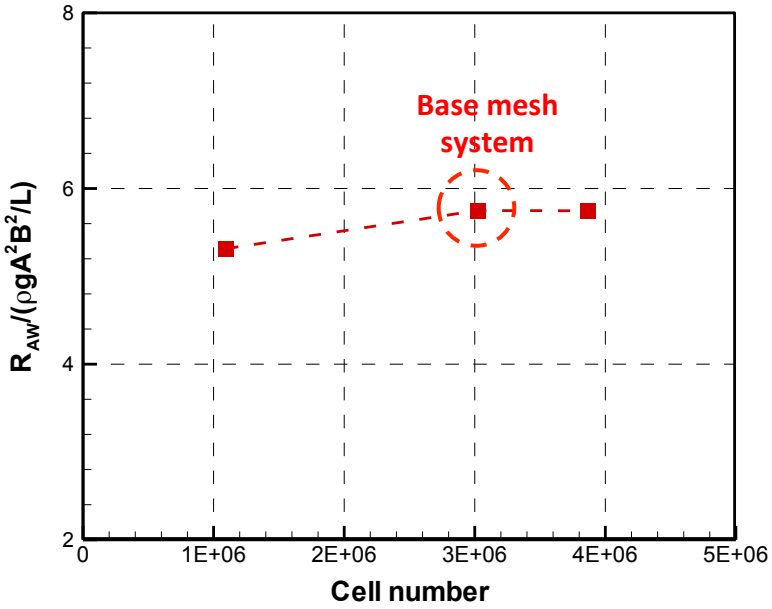
- Unsteady Reynolds-Averaged Navier-Stokes (URANS) approach
- FVM and VOF methods
- Dynamic Fluid Body Interaction (DFBI) for the ship vertical motions
- Added resistance for regular waves in time domain

Grid Convergence Test for CFD

- Meshes & boundary conditions including mesh convergence test

Mesh	λ/Δx	H/Δz	Te/Δt
Coarse	70	14	181
Base	100	20	256 (2^8)
Fine	140	28	362





Test Cases for CFD Methods

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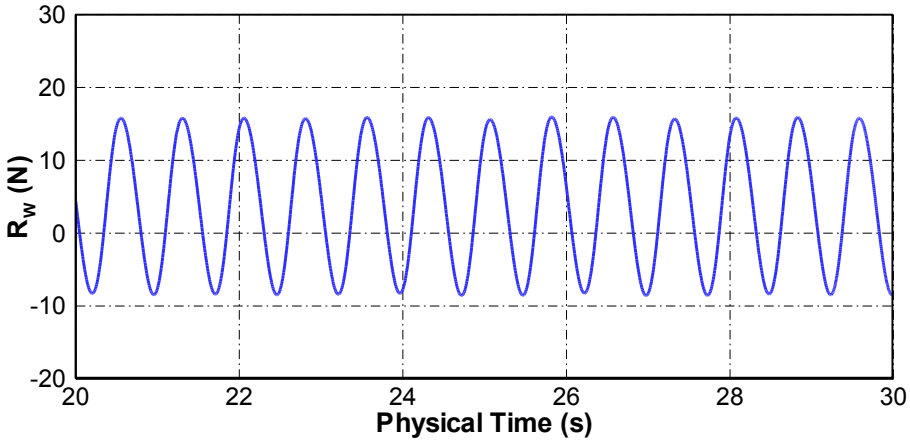
- Simulations at 15.5kts as the ship design speed to be conducted to be compared with existing experimental results for validation.

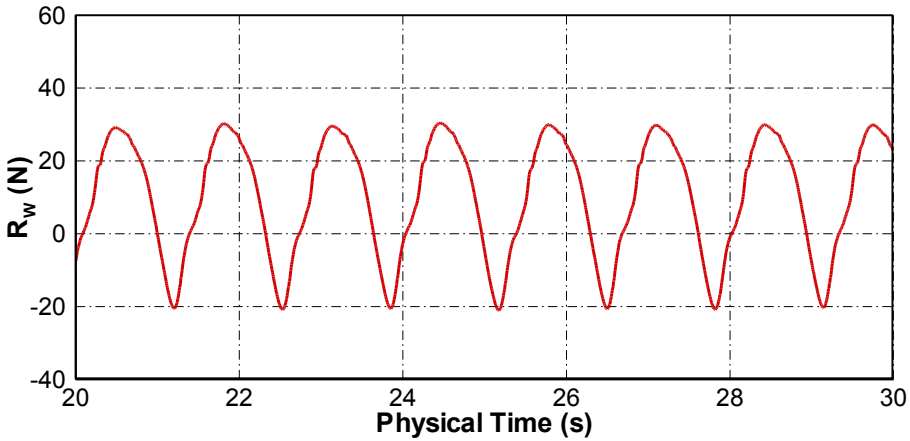
Cond. No.	Vs [knots]	Wave length (λ/L)	Wave height (H) [m]	Steepness (H/λ)	fe [Hz]	Te [sec.]
C00	15.5	Calm water	-	-	-	-
C10		0.30	1.60	1/60	1.8835	0.5309
C11		0.50	2.67		1.3293	0.7523
C12		0.75	4.00		1.0186	0.9818
C13		1.00	5.33		0.8476	1.1798
C14		1.20	6.40		0.7560	1.3227
C15		1.40	7.47		0.6872	1.4552
C16		1.60	8.53		0.6332	1.5793

Time History Data (CFD)

- Total resistance in short and long waves (15.5kts)



(λ/L=0.5, Te=0.7523 sec.)♪

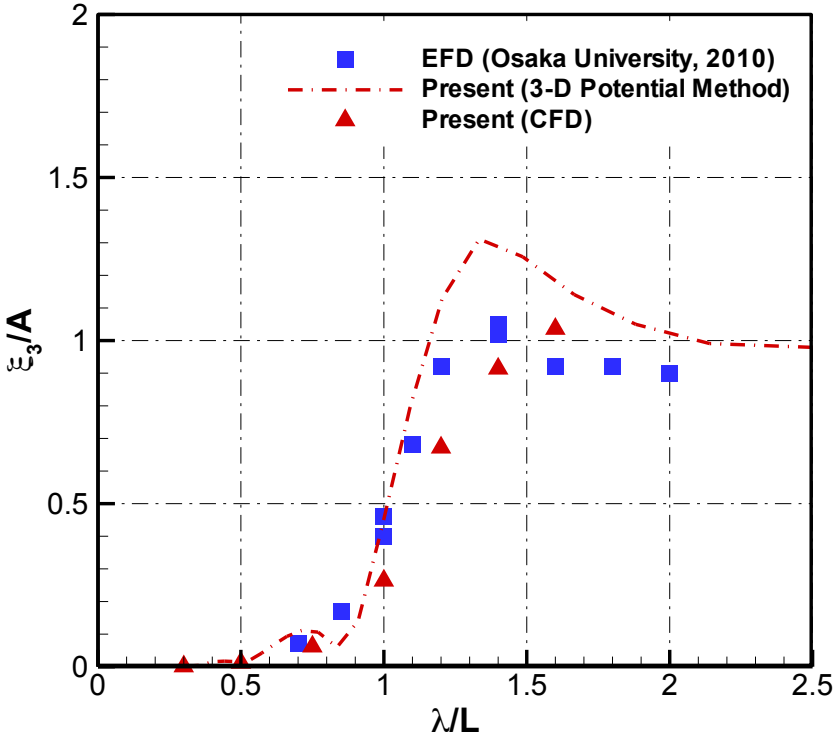


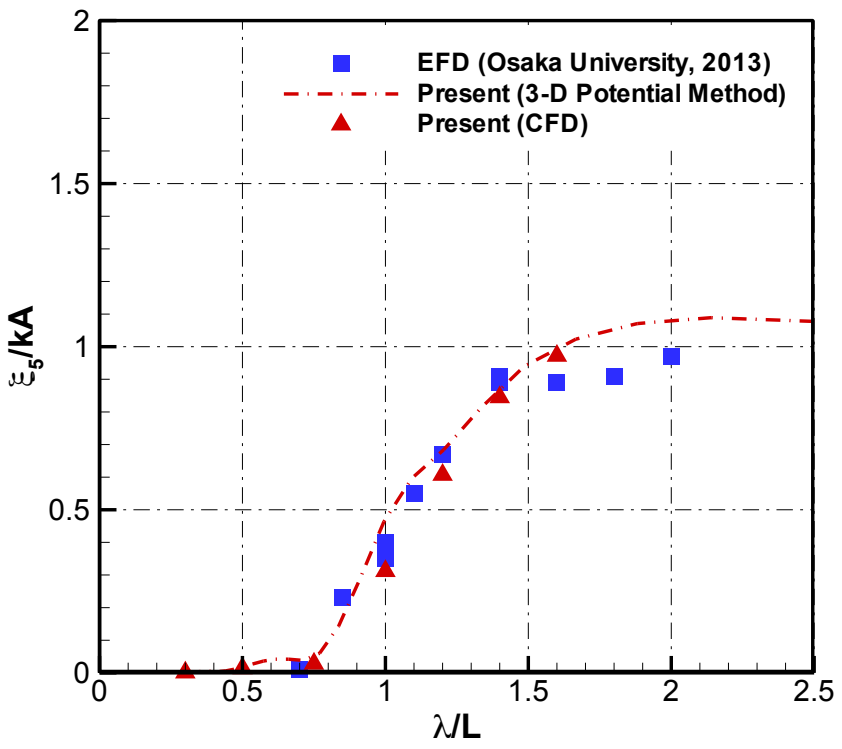
(λ/L=1.2, Te=1.3227 sec.)♪

Ship Vertical Motions

- Heave and pitch responses in head waves (Vs=15.5kts)

  Verification for ship motions is required because added resistance due to waves is proportional to the relative motions (typically, heave and pitch motions) and inaccuracies in the predicted motions will be amplified in resistance errors.

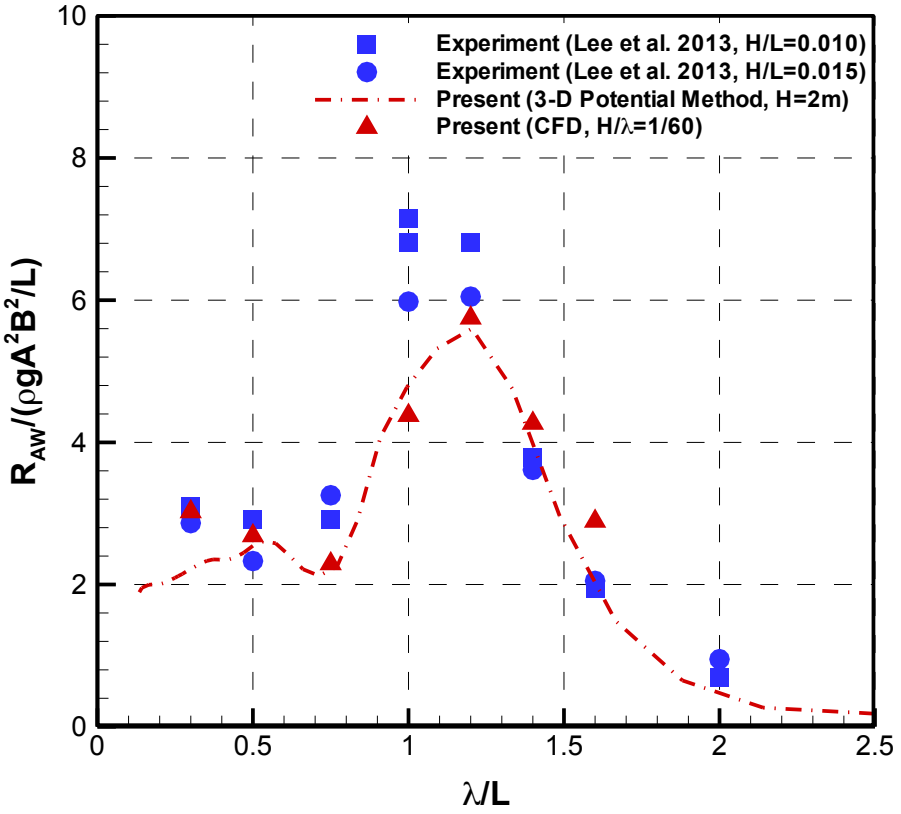




Added Resistance in Waves

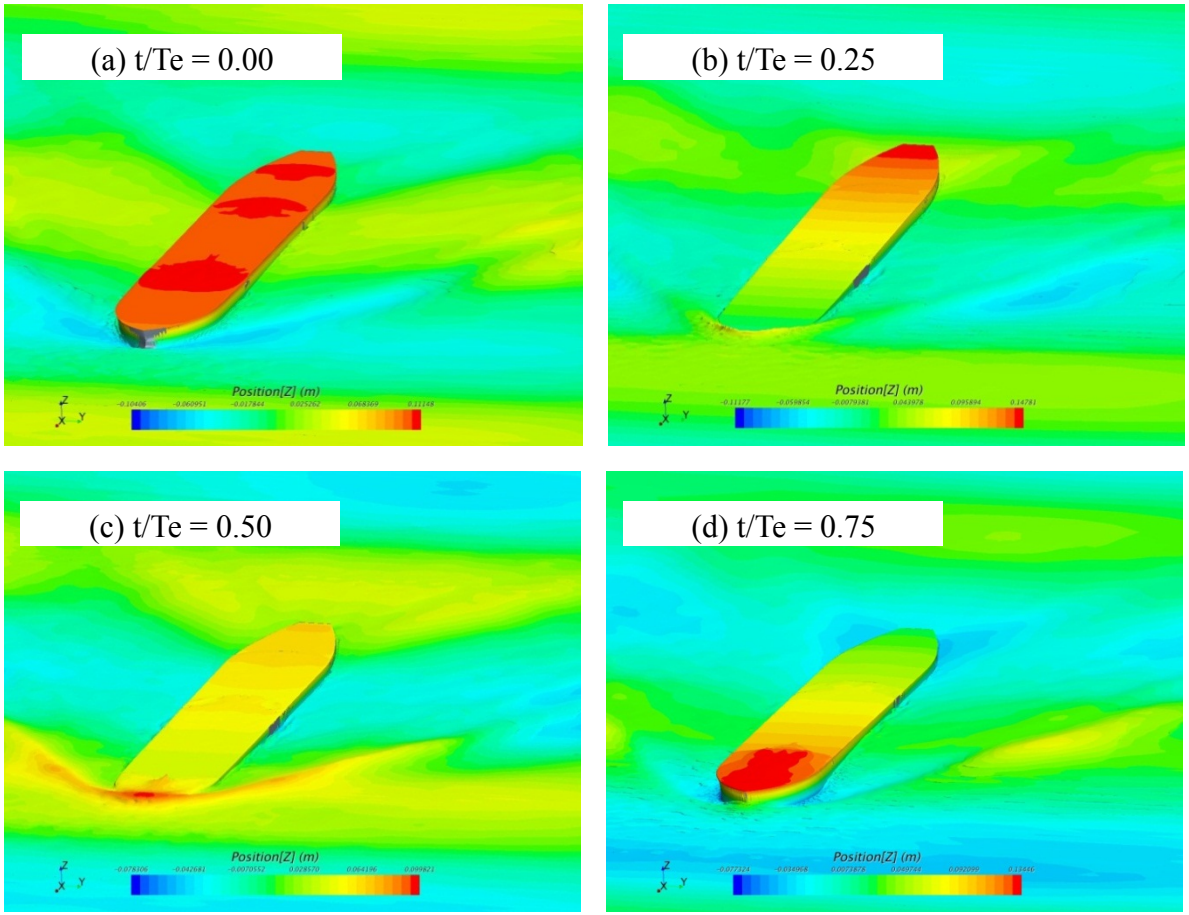
- Added resistance coefficients in short and long waves (Vs=15.5kts)

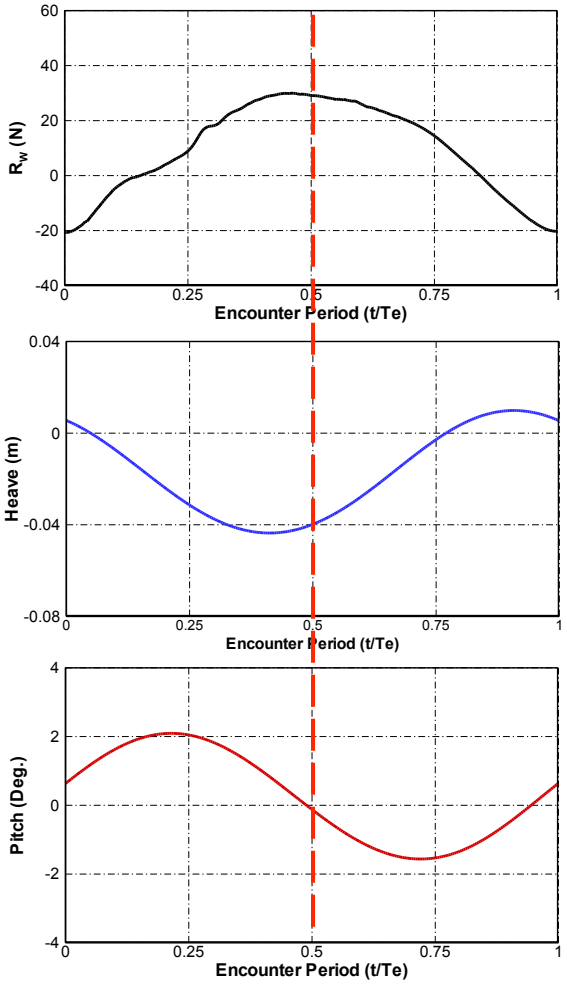
  Investigation on the added resistance has been done in not only long wave but also short wave (λ/L=0.3~0.75) conditions.



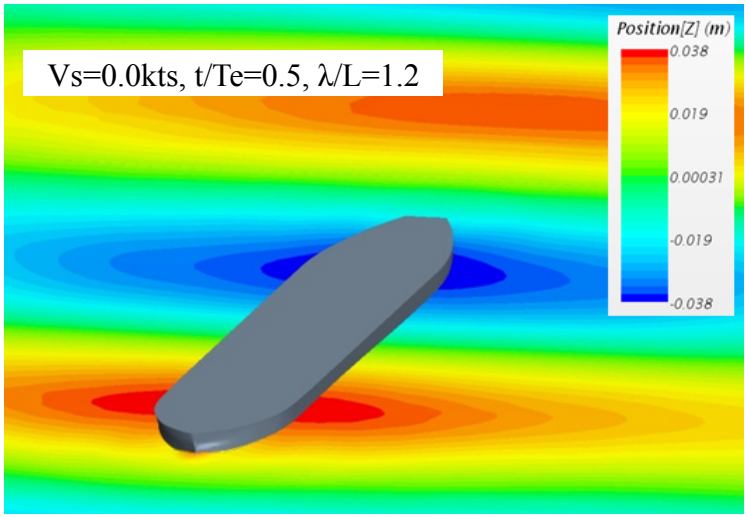
Numerical Results (CFD, Vs=15.5kts)

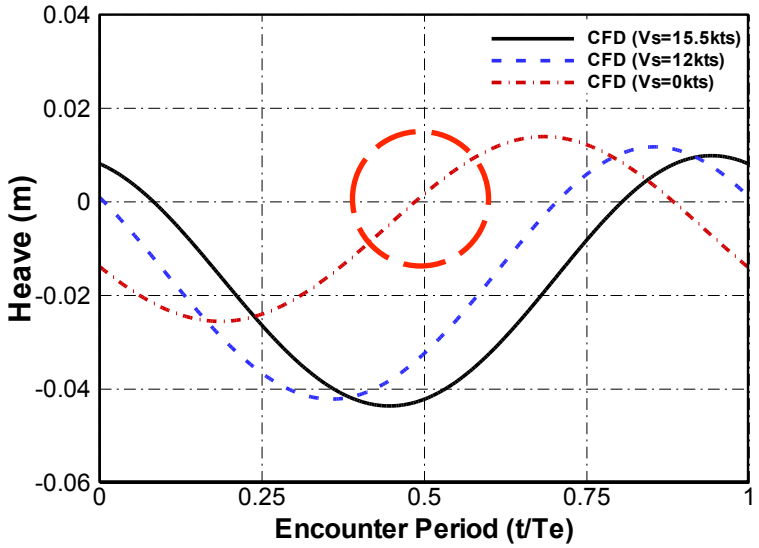
- Periodic wave patterns over a period of encounter (15.5 knots, λ/LBP=1.2)

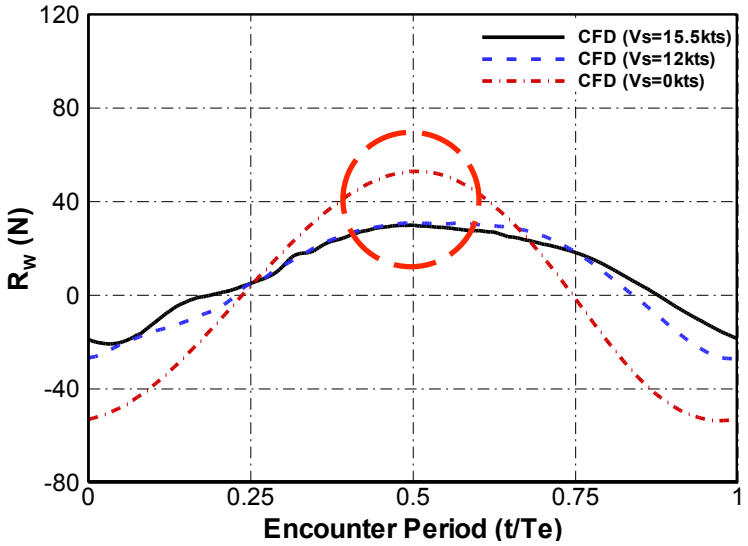


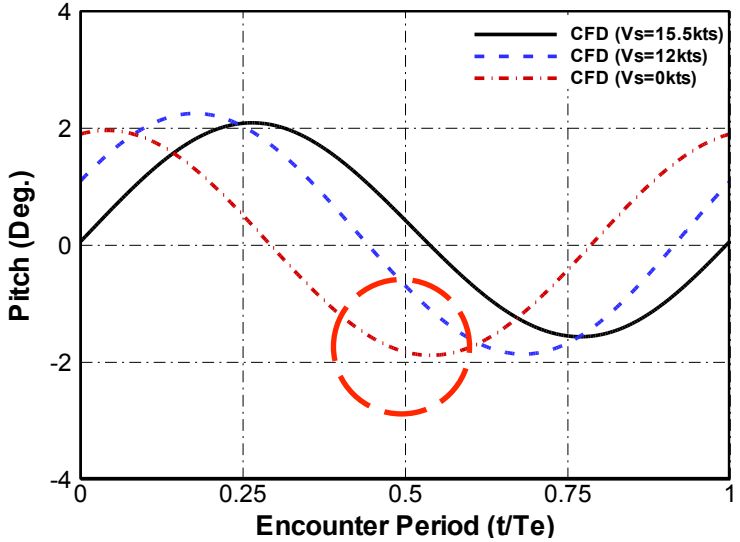


Numerical Results (CFD, Vs=0.0kts)









Conclusions

- Wide range of studies have been performed for the prediction of the added resistance and the ship vertical motions in waves using the 3-D potential flow and the CFD methods.
- The optimal mesh system has been investigated and established from the grid convergence test.
- Unsteady wave patterns and the added resistance with ship motions in time domain are simulated and analysed using CFD.
- It is observed that the total resistance force in the time domain at the stationary speed (Vs=0.0kts) could be larger than that at the design (15.5kts) and operating speeds(12.0kts).

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